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ABSTRACT
This paper explores the role that knowledge of the innovation process plays in advancing world development. Other factors, such as political and economic influences, are also considered. (MLH)

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ADOPTION AND ADAPTION STRATEGIES IN WORLD DEVELOPMENT

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I. Introduction

Innovation plays an important role in world development through both the development and diffusion of innovations. The latter enables ~~geopolitical units~~ nations to make use of innovations developed elsewhere, while the former brings new products and processes into the world. The main objective of this paper is a preliminary exploration of the role that knowledge of the innovation process may play in advancing world development.

Knowledge about innovation can be brought to bear most directly on the development of the capacity to innovate, including all aspects of innovation. This development of technical capacity should be carefully distinguished from economic development--which includes production of goods already existing--and political development. A voluminous literature exists on the problem of economic development, dealing with both the so-called "developed world" and the "underdeveloped countries." It is not the purpose of this paper to survey that literature though it bears heavily on the development of technical capacity and should be integrated with any careful and complete treatment of technological development. The treatment of the process of developing technical capacity begins with the suggestion of an interesting analogy between the innovation process itself and the development of technological capacity.

II. An Analogy

In discussing the innovation process as a whole, the Georgia Tech study (Kelly et al. 1975) accepted for analytic purposes the distinction of the process into phases. The two major phases dealt with the development and the diffusion of innovations. The development phase was further subdivided into two subphases: problem definition and idea generation and research and development. While an ecological model of innovation was adopted and the linear sequential model of process phases explicitly rejected because of the mutual causal relationships existing between the activities of the various phases (Kelly et al. 1975, Ch. 1), there remains a sense in which at least for analytical purposes a sequence can be said to exist. To clarify this sequence, a typology of innovative activity ranging from the lowest to the highest cognitive demands on the innovator (organization or person) can be developed (see Rossini et al. 1975):

1. Adopter--makes use of an elsewhere preexisting product or process. The adopter requires knowledge of his needs and the relevant properties of the technological entity he intends to adopt.
2. Adapter--adapts through relatively minor modifications an elsewhere preexisting product or process to the different conditions of a new environment. The

adapter, in addition to the adopter's knowledge, requires some small knowledge of the workings of the technology he intends to adapt.

3. Incremental Innovator--significantly improves the capabilities of a technology whose main features are already known. Besides the knowledge possessed by the adapter, the incremental innovator requires detailed basic knowledge of the technology being dealt with as well as pertinent scientific results. He needs the capability to conduct technological research.

4. Discontinuous Innovator--creates a new product or process which breaks significantly with the technological state-of-the-art. (For the purposes of this paper discontinuous means discontinuous relative to the current state-of-the-art rather than discontinuous in a particular, limited context.) In addition to the knowledge capabilities of the incremental innovator the discontinuous innovator may require the capability of basic scientific research.

The dimension of knowledge was chosen to illustrate the progressive differences of this collection of ideal types. However, different dimensions, such as organizational structure or personal characteristics (see Kelly et al. 1975, Ch. 3), might be considered as well.

This typology has a rough parallel to the phases of the innovation process. Each level of innovative activity corresponds approximately to an increasing capability for innovation. But instead of increasing in the direction of idea generation to diffusion, the original putative sequence of the innovation process, the increase is in the opposite direction. The adopter has mastered diffusion. In addition to this the adapter has development capabilities. And the incremental innovator includes technical research in his portfolio of capabilities, while the discontinuous innovator has basic scientific research and idea generation _ab initio_ capabilities. Thus the "innovator" may be said to develop capacity, because of the complexities of knowledge involved, from diffusion to idea generation.

At this point, however, a warning is in order. Such a typology and analogy neglects crucial factors which will be operative in the case of any development in the real world. Economic and political factors cannot be neglected as they are in this treatment, and our future research will reflect such realities as formation of capital necessary for production and the governmental framework within which technological capacity is developed; furthermore, neglecting these factors, distinctions must be made among fields of technology for innovator units may be at different stages in different technological areas depending on endowments and other contextual constraints.

Besides coinciding with the phases of innovation this typology of innovative activity can be set into correspondence with the three phases of international technology transfer discussed by Hayami and Ruttan (1971, pp. 174-6). Although they were concerned with the international development of agriculture, their phases may prove useful beyond this sector. These phases are:

1. Material transfer characterized by the transfer of products and processes without any systematic attempt at local adaptation.
2. Design transfer through the transfer of certain designs via blueprints, books, etc. During this phase imports are made in order to obtain new models or copy designs. Domestic production of imports of the previous phase is begun. Some initial, simple capability for development is developed.
3. Capacity transfer through the transfer of technical and scientific knowledge and capacity which enables the production of locally adaptable technology following the proto-type technology which exists

abroad. Incremental innovations take place in the course of this development.

Technological progress in this analysis consists of moving from material transfer to capacity transfer. Stage 1, material transfer, corresponds closely with adoption. The second stage, design transfer, is similar to adaption except that design transfer includes a production capability--an appropriate inclusion since Hayami and Ruttan are economists--but a capability which this analysis excludes. Capacity transfer is loosely similar to incremental innovation except that here, too, production capability is included. The usefulness of technology transfer models ceases at the level of discontinuous innovation for here the innovation is generated from the beginning and not brought in. Thus discontinuous innovation has no parallel in Hayami and Ruttan's typology.

With the analogy between the innovative process and cognitively progressive stages of innovative activity laid out, the question of development can be approached from the perspective of knowledge. Before turning to the specifics of development, it is useful to review our knowledge of knowledge in innovation.

III. The Role of Knowledge in Innovation

Following the analytic sequence from adoption to discontinuous innovation we first consider the role of knowledge in adoption. In their studies of diffusion Mansfield et al. (1971) found that adoption is slowed by lack of knowledge and that adopter units (in this case firms) with more highly educated management tend to adopt earlier. In their efforts to explain results as to why earlier adopters had more education, Nelson and Phelps (1966) suggested that in a technologically progressive economy management is a function requiring adaptation to change and the more educated a manager is, the quicker he will introduce new products and processes.

It is important to note that these results deal with levels of education and not with any specific pieces or blocks of knowledge. Thus the effect of education is in the creation of a social climate or frame of mind which is oriented to favor innovation. This same sort of background effect of knowledge came through clearly in the work of Langrish et al. (1972) concerned with the development, rather than the diffusion, of innovations. Considering the role of scientific knowledge in facilitating technological innovation, they stressed indirect, rather than direct, effects (p. 40):

> First, curiosity oriented science, practiced largely in academic institutions, provides techniques of investigation. Second, it also provides people trained in using these techniques as well as in scientific ways of thought in general...Third, science enters innovation already embodied in technological form. It may be relatively rare for a piece of curiosity oriented research to

generate a piece of new technology, but once this process has occurred, the technology can be used over and over again and developed into more advanced technology.

Moving to more definite forms of knowledge, the knowledge of the specific needs which the innovation is intended to meet is of paramount importance, though this topic is, in its explicit form, missing from the literature. In the case of needs, specific technical needs with measurable parameters might usefully be distinguished from economic needs such as profit maximization or political needs such as maintaining the stability of the regime. The importance of needs information in innovation has been hypothesized by Kelly et al. (1975). Its importance lies in that demand (as expressed by needs) rather than supply (e.g., of scientific or technical knowledge) is the dominant determinant of innovation (see Schmookler 1966 and the review article by Utterback 1974). Knowledge of needs determines (with the knowledge of constraints) the choice for adaption among competing innovations. Likewise (as the references cited above indicate) the development of innovations is spurred by the expression of need through market demands.

Technological knowledge operates to facilitate the development of innovations. Preexisting configurations of technological knowledge focus technological development. An "imbalance" or "reverse salient" (Hughes 1971) refers to a bottleneck of knowledge, breaking of which would advance technology along a broad front.

A sequence of imbalances is to be found in the textile industry in the 18th century. Richard Kay's invention of the "flying shuttle" speeded up the weaving process, upsetting the usual ratio of four spinners to one weaver; either there had to be many more spinners to supply a weaver with sufficient thread or yarn, or else spinning had to be similarly quickened by innovations in that field. A series of inventions by James Hargreaves, Richard Cartwright, and Samuel Crompton speeded up the spinning process. Then Cartwright set about mechanizing the weaving operation in order to take full advantage of the now-abundant yarn produced by the new machines. The result was the power loom. These machines lowered the price and hence created a large new market for cotton textiles. Another bottleneck developed in the supply of raw cotton, where the chief difficulty lay in the amount of labor involved in picking the seeds from the bolls. This problem was solved by Eli Whitney's invention of the cotton gin, which more than tripled the amount of seed-free cotton which could be produced per man per day. Thus, innovations in one field produced a need for inventions in other related fields (Mantoux 1961, Part II, Chapters 1-2).

If a unit lacks sufficient technical knowledge to be ready for an innovation, that innovation will fail as Polzunov's invention of a steam engine in 18th century Russia failed when its boiler leaked and no one could repair it (Zvorikine et al. 1962, pp. 138-9).

These observations about technological knowledge can be used to support the contention that a broad technical knowledge base in an area is needed for innovation beyond mere adaption. Indeed the predominant evidence indicates that technological knowledge alone, without direct application of basic scientific knowledge, is sufficient for the development of innovations. This emerges very explicitly from project hindsight (Sherwin and Isenson 1966) in which the Department of Defense studied the role of basic science in weapons development and found essentially that it had none. The work of Achiadelis et al. (1971), Myers and Marquis (1969), and Langrish et al. (1972) supports this negative view in broader contexts. An inspection of the case studies of Jewkes et al. (1969) also supports this claim.

But as Langrish et al. noted (above) there are indirect effects which are quite significant. Direct benefits appear to be distant. It is a long way intellectually from Einstein's theory of relativity to a working nuclear reactor. But without the former, or some surrogate, the latter appears impossible.

Thus there must be a connection, albeit distantly and through intermediaries.

TRACES (1968), an aptly named project sponsored by the National Science Foundation, sought the such connections. Although it found them, in the case of several important innovations, such as the oral contraceptive, these connections were almost always quite distant from the point of innovation. Examples of the immediate impact of basic scientific research programs on specific innovations such as the work of Shockley and his solid state physics group at Bell Labs on the transistor (Weiner 1973; Nelson 1962) and Carothers and his polymer chemistry group at Du Pont on nylon (Mueller, 1962) are simply exceptions to the general rule which have the common property that they are breakthrough, discontinuous innovations.

With the typology of the second section and the data of the third, and keeping well in mind the caveats mentioned throughout, especially as to the limitations of this treatment, strategic considerations in development can now be addressed.

IV. Strategic Considerations

This section proposes to discuss with some degree of specificity the types and levels of knowledge needed to develop and maintain the four levels of technological capability. These were mentioned casually as the typology was introduced, but here they will be amplified and justifications will be advanced. No attempt will be made to apply these considerations directly to specific situations, but they could apply to geopolitical units wishing to plan their technological destinies and subdivisions of these units. The perspective taken will be that of the innovator. It should be clear that the same unit can be at different stages of development relative to different technologies.

A. Adoption

Information relating to needs is paramount in the case of adoption. Adoption consists of a choice of existing technologies. Knowing what is needed is a step toward intelligent choice. This constitutes an argument for planning. Clearly some technical knowledge is necessary. In this case technical capability on the Bachelor's level would seem to suffice along with mechanisms for establishing needs and determining the options available to meet them. The importance of need and market knowledge cannot be overstressed. It is important to note that needs are multi-dimensional, containing social, political, and economic dimensions as well as technical. The adoption should always be viewed as adoption into a multi-dimensional context and the congruence of the innovation with the existing situation is important (for examples in different contexts see Spicer 1953 and Bright 1964); sensitivity to the pro-adoption propaganda of propagators may prevent costly errors.

B. Adaption

In adaption technical knowledge takes on greater importance. Here it is necessary to know how things work as well as what they do as measured in various parameters. A state-of-the-art technical capability is not required. Both for adaption and production of pre-existing designs of relatively unsophisticated technologies, significant research capability is not necessary. However, developmental skills of the "cut and try" variety are needed. Need and market information, as with adoption, is necessary. However, its relative emphasis decreases as the need for technical skills becomes more pronounced. Scientific knowledge is not an important factor here. Some basic scientific background of technical personnel is appropriate, to set a tone, but after a point such background is "window dressing." ~~To assure a technically progressive environment, technical training should be broad based rather than elitist.~~

C. Incremental Innovation

At this point state-of-the-art or near state-of-the-art technical capability becomes highly desirable. The ability to conduct technical research is crucial for any significant improvements. This capability may have some spillage into some applied areas of science, but as yet basic scientific research is simply not needed. What is needed, however, is the ability to translate basic scientific results into usable forms for technological innovation when and where these are needed. Much of "pure science" knowledge still remains decorative rather than useful, but the gap between incremental innovation and basic science is not nearly as pronounced as the gap between basic science and adaption. In such an environment university level capabilities of education are necessary. Here too market and need information are essential, but the increase in complexity of the technical base makes this information more complex.

D. Discontinuous Innovation

At this stage innovation confronts the unknown. In the other three classes of innovative activity there was a reference frame which oriented the activities. Someone had gone that route before. Here there is no firm guideline. Needs to be met by technologies whose impacts are not clearly understood are needs likely to be changed. The enhancement of the capability for novelty may be helped by the proximity of relatively free flowing basic research. The most immediate contacts between scientific knowledge and technological innovation lie in discontinuous innovations. The problem of bringing the basic science to the technologist in usable form is a difficult problem and one whose solution has, in the past, contributed to innovation (see Brittain 1970). The importance of another form of knowledge--knowledge of the future consequences of technologies through technology assessment (see Hetman 1973 for a good overview)--is apparent in the context of the unknown. Historically technology has significantly shaped and altered our world. Knowing, insofar as we can, what will happen if novel technologies of a certain type are introduced helps plan for the future. In a situation like this one where the frontiers of all types of knowledge are being probed, the problem of information overload may become acute as it has ~~become acute~~ in our society. The difficulty of getting the right piece of knowledge to press on with ongoing work when the sources of knowledge are so many and so dispersed is considerable. This is the hardest form of innovative activity to deal with as it is unprecedented.

V. Concluding Remarks

Knowledge plays an important role in innovation. In a given situation the progressive development of knowledge may lead to an enhancement of innovative capability. The main thrust of this paper has been to hypothesize a coordination between innovative capability and types and levels of knowledge. But there are many other factors in development besides the technical, and more dimensions of development besides knowledge. ~~Any realistic effort at using our knowledge of innovation to understand development needs to include more along these two dimensions.~~ At the very least political and economic factors impinging on the process of technical development should be included in the treatment. Likewise at least organizational and behavioral dimensions should be included.

Yet this treatment, limited and idealized though it may be, seems to suggest the potential fruitfulness of the analogy of the inverse progression between the development and the diffusion of an innovation and the process of the development of technical capabilities as illustrated in the case of knowledge. It may suggest a framework for dealing more extensively with technical development as a phenomenon in its own right and thus serve as a useful means for linking the innovation and development literatures.

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